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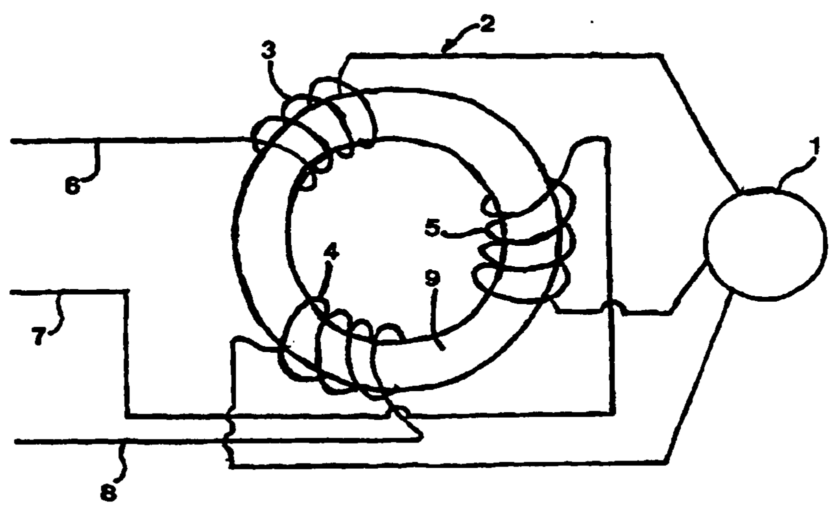

(57) Abstract

A reactor comprises a plurality of windings (3–5) each adapted to be connected to a phase (6–8) of a multiphase alternating voltage. The windings are configurated so that they upon connection to said voltage are influenced substantially by the same magnetic flux. At least one of said windings is at least partially formed by a cable in the form of a flexible electric conductor with an envelope able to confine the electric field created around the conductor.

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A reactor

FIELD OF THE INVENTION AND PRIOR ART

The present invention relates to a reactor comprising a plurality of windings each adapted to be connected to one phase of a multiphase alternating voltage.

Each phase of said multiphase alternating voltage has at least one winding of the reactor connected thereto, but it is for sure possible that the number of windings are higher than the number of phases and that two or more windings are connected in parallel or in series to one or more of the phases.

Such a reactor may be used within the most different fields, in which there is a desire to be able to influence electromagnetic quantities under certain conditions.

For illuminating the invention and the problem to be solved by the invention, but accordingly not in any way restricting the invention, such a reactor in the form of a device for protecting different types of electric equipment when faults arise in electric apparatuses or networks for transmission or distribution of electric power or upon occurrence of asymmetry of said multiphase alternating voltage will be discussed hereinafter.

It is pointed out that the number of phases of the multiphase alternating voltage may be any higher than 1, but the three phase voltage case will be discussed hereinafter, since it is the most common multiphase voltage. Furthermore, it is emphasised that

the invention is not restricted to any particular voltage range, but it is applicable to low, medium as well as high voltage.

A reactor of this type for the purpose last mentioned is preferably connected so that it is connected in series between the alternating voltage supply and an electric apparatus or the network in question. Should the apparatus or the network be connected to two or more alternating voltage supplies having possibly different voltage levels, it may be suitable to place a reactor of this type in series between the apparatus or the network and one or more of the supplies. This may for example be the case for a transformer or a transmission line. The change of voltage over such a reactor may be explained to be created through the change of the equivalent inductance felt by the currents in the different windings upon particular disturbances, and by that the equivalent reactance of the reactor is changed.

There is often a desire that the reactor shall not be noticed when supplying the alternating voltage without any disturbance, i.e. the voltage drop thereover should be as low as possible. However, it is highly desirable to obtain a very high voltage drop over the reactor upon occurrence of any type of disturbances for by that counteracting the disturbance and protect said equipment primarily against high currents. These two desires may not be combined in the reactors of this type already known, but it is necessary to make a compromise. This means that if there is a need of a very high voltage drop and by that a powerful current limiting property of the reactor upon an asymmetry fault, it has been necessary to accept a voltage drop being not neglectable thereacross also during normal operation. This has mostly resulted in the choice of an intermediate way when dimensioning such reactors, so that they get "medium good" in both cases.

A normal three phase reactor has a plus- and a minus sequence inductance being at least as high as the zero sequence inductance thereof. This means that if a zero sequence current gen-

erated at for instance an earth fault is to be limited substantially with this type of reactor, the voltage drop will be comparatively high also at symmetrical alternating voltage. No zero sequence currents are present in this case, but when an asymmetry in the alternating voltage between the phases occurs as a consequence of a fault or other disturbances zero sequence currents are produced and they should be limited. A reactor of this type tries to achieve this limitation by generating a high voltage drop by introducing a higher inductance. The zero sequence inductance is comparatively low and the current limiting effect comparatively bad in a three leg reactor, whereas the zero sequence inductance will be approximately as high as the plus and the minus sequence inductances in a five leg reactor. This means that the latters have to be made comparatively large for making the zero sequence current to feel a sufficiently high inductance for making the current limiting influence of the reactor good.

SUMMARY OF THE INVENTION

The primary object of the present invention is to provide a reactor of the type defined in the introduction, which makes it possible to deal with the problems discussed above and associated with the reactors already known. A secondary object of the invention is to provide a reactor having such a construction that it has an improvement with respect to reactors of this type already known with respect to manufacturing simplicity, reliability and low power losses in operation, price etc, which makes it commercially more interesting than the reactors already known.

The primary object is obtained by configurating the windings of a reactor of this type so that they when connected to said voltage are influenced by substantially the same magnetic flux.

By configurating said windings so that they are influenced by substantial the same magnetic flux, it is possible to configurate them so that this magnetic flux will be substantially zero in the

normal case, i.e. in symmetrical supply of the multiphase alternating voltage, which means that the different currents will then in principal not feel any inductance at all and the voltage drop over the windings will be a minimum. However, the reactor may be constructed in such a way that the selfinductance of the different windings is very high and by that the inductance felt by a zero sequence current, i.e. a current occurring upon asymmetry, will be very high and by that a very high voltage drop is required for driving such a current, which would act strongly current limiting and keep such a zero sequence current at an acceptable low level. Since a reactor according to the invention does not disturb the normal operation it will in this way be possible to make the zero sequence inductance much higher than would be suitable for a traditional reactor. Electric equipments, for example transmission networks, may in this way be efficiently protected against very high earth fault currents or short circuits when trees are falling on a network line or the like. The properties of the reactor may also be utilised in a filter for the third harmonic and multiples thereof. The reactor may efficiently filter these harmonics away, while the fundamental current will be uninfluenced. Thus, a combination of current limiting device and a third harmonic filter may be obtained by one and the same reactor, which may be very interesting also from the cost saving point of view. It is pointed out that the reactor limits the current passively, i.e. the zero sequence current is automatically limited. Thus, there is no need of any particular detection of the zero sequence current, which then would activate a measure, which limits the zero sequence current. This means that the reliability of the reactor according to the invention is high and the maintenance thereof may be small. This is a great advantage in many electric plants. However, it may sometimes be interesting to detect a fault current created for other purposes, for instance for controlling a breaker. This detection being completely independent of the limitation of the fault current is then most easily carried out by any form of detection of the magnetic flux in common.

According to a preferred embodiment of the invention the number of phases, the number of windings, the winding direction of the windings and the number of turns per winding are so selected that the sum of the currents flowing in said windings and driving the magnetic flux in common is substantially zero when the windings are symmetrically supplied with the multiphase alternating voltage. Thus, it is by this obtained that the inductance influencing these currents gets very low at the symmetrical supply. The advantages thereof appear from above.

According to another preferred embodiment of the invention the number of phases are three, and the invention is particularly well suited for three phases, since it will in such a case be easy to obtain that the sum of the current flowing through the windings and driving the magnetic flux in common is substantially zero upon symmetrical supply as a consequence of the phase shift of 120° presented by these currents. The sum of the currents driving the magnetic flux in common gets zero if the winding turns for example run in the same direction in combination with a number of winding turns of the windings belonging to the respective phase being equal.

According to another preferred embodiment of the invention the windings belonging to different phases are arranged close to each other. It gets by this easier to ensure that the windings will be influenced by substantially the same magnetic flux and the size of leakage flux will be kept low. This is a feature often desired in the case of an air reactor, but it is not just as important in a reactor having a magnetised core, although it is most often desirable also there.

According to another preferred embodiment of the invention the windings are led through a closed magnetic circuit in common, and according to a further embodiment the reactor comprises a closed magnetic circuit in common surrounding the windings. By

using such a closed magnetic circuit it is in a simple way obtained that the windings will be influenced by substantially the same magnetic flux, said magnetic flux running through this magnetic circuit, or core, and that a very high inductance may be felt by the asymmetry contribution to a current upon occurrence of asymmetries in the alternating voltage supplied. The voltage drop may be changed within a very wide range, i.e. the "swing" of the reactor will be large, and the current limiting properties may by that be improved if substantially the entire core is magnetic.

According to a preferred embodiment of the invention the core of the reactor is magnetizeable and forms a substantially closed loop. This may keep the main part of the magnetic flux inside the core and leakage fluxes may be restricted so as to obtain the lowest voltage drop possible in symmetrical supply.

According to another preferred embodiment of the invention the windings run with the winding turns thereof around and surround said magnetic circuit completely or over portions and in the case of an air reactor, i.e. a reactor having no magnetizeable core for the magnetic flux, it its advantageous if a substantially completely surrounding takes place, since the leakage fluxes will in this way be kept low. An advantage of an air reactor is that it will be less expensive, since it has no expensive core. An air reactor according to the invention could also be dimensioned for higher magnetic fields than would be managed by a closed reactor, so that the entire construction may be compacted. A disadvantage is that the current limiting ability upon occurrence of asymmetries will be lower for a reactor with an air core.

According to another preferred embodiment of the invention the magnetic circuit surrounds a circular area. Such a design means in the case of a magnetizable core forming the circuit that less material will be used therefor, and the reactor may be made to a

lower cost. The core may in this case both be magnetic and non-magnetic (air core).

According to another preferred embodiment of the invention the magnetic circuit surrounds a rectangular area, which means that a traditional magnetic core may be used in the reactor.

According to a further preferred embodiment of the invention the magnetic circuit surrounds a triangular area, which may be an advantage from the manufacture point of view, since in the case of three phases each triangle leg could be designated for the winding or the windings of a particular of said phases.

According to another preferred embodiment of the invention the magnetic circuit has at least one air gap. It is by this obtained that the inductance of the reactor will be substantially linear, which in some cases may be more important to obtain than the somewhat better current limiting ability resulting from a closed magnetizeable core.

The secondary object of the present invention is obtained by making at least one of said windings of a reactor according to claim 1 at least partially formed by a cable in the form of a flexible electric conductor with an envelope being able to confine the electric field generated around the conductor.

By the possibility to substantially confine the electric field occurring as a consequence of said electric conductor in the insulation system the reactor may be more efficient, i.e. losses generated therein may be reduced. The reduction of losses results in its turn in a lower temperature of the reactor, which reduces the need of cooling and makes it possible to construct cooling arrangements possibly existing in a more simple way than without such construction of said windings. The cable may be made in the form of a flexible cable, which means substantial advantages with respect to manufacturing and mounting in comparison with

stiff windings prefabricated having been traditionally used until today. Furthermore, the use results in an insulation system obtained in this way with absence of gases and liquid insulation materials with the disadvantages associated therewith.

Another advantage of this embodiment is that exactly in the case of a magnetizeable core of the reactor being common to the windings it will be considerably more easy to take care of the insulation between the windings than in conventional coils.

According to another preferred embodiment of the invention all the windings are formed by a said cable. This makes it possible to utilise the advantages of such a cable to an optimum, and another embodiment of the invention enabled through the use of such a cable, namely an intermixing of different windings at least partially in the sense that winding turns belonging to the same winding have winding turns belonging to another winding and another phase entirely or partially therebetween, may be utilised entirely. Through such an intermixing of the windings leakage inductances of the reactor may be reduced, so that for a given inductance in asymmetry the inductance felt in symmetry may be reduced further. This inductance in symmetry is preferably exclusively formed by such a leakage inductance. Any such extended intermixing of windings with each other is for sure not possible when using conventional insulation technique in reactors.

Further advantages as well as advantageous features of the invention will appear from the other dependent claims and the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the appended drawings, below follows a description of preferred embodiments of the invention cited as examples.

In the drawings:

Fig 1 is a very schematic view illustrating a possible use of a reactor according to the invention,

Fig 2-9 are cross-section views of reactors according to preferred embodiments of the invention, and

Fig 10 is a perspective view of a cable being particularly well suited to be used so as to form windings of the reactors according to the invention, in which different parts of the cable have been removed for illustrating the construction thereof.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

It is schematically illustrated in fig 1 how a reactor according to the invention may be connected in the network for supplying a three phase alternating voltage to a load 1, for example an alternating current motor. A reactor 2 comprises three windings 3-5, which are connected to a phase 6-8 each of the alternating voltage network. The windings are led around a magnetizeable core 9 in common of iron or iron alloy. The winding turns of the different windings run in the same direction as seen in the direction away from a location for connection to the multiphase alternating voltage, and they have the same number of turns. This means that when symmetrically supplying a three phase alternating voltage the sum of the currents flowing in the windings and driving the magnetic flux in common therefor through the core will be substantially zero, so that plus and minus sequence currents in the respective winding will feel a very low inductance, even if the self-inductance for the respective winding would be very high. No zero sequence current occurs in symmetry of the alternating voltage supply.

The voltage U_3 induced in the winding 3 will for example in ideal cases, the mutual inductance of the phases being considered to be just as high as the self-inductances for the respective phase, then be:

$$U_3 = L_{33} \frac{d(I_3 + I_4 + I_5)}{dt} \qquad (1)$$

In which L_{33} is the self-inductance of the winding 3 and I_3, I_4 and I_5 the currents through the respective winding. It appears from (1) that for the case when the sum of the currents in the phases is zero (plus sequence and minus sequence current) the voltage induced in the phases will be zero, since the equivalent impedance is zero and by that no influence upon the circuit occurs, in spite of the fact that L_{33} may be very high. Should however a zero sequence component be present in the phases this contribution will feel a very high voltage drop across the reactor if L_{33} is assumed to be high. This voltage drop corresponds to a high impedance and is by that current limiting for zero sequence currents. Such an asymmetric load could result from a short circuit of one of the phases to ground, and the reactor will in such a case act strongly limiting upon the magnitude of such a short circuit current and protect the motor, the power network, the generator, the transformer or any other electric equipment.

It is shown in fig 2 how a reactor according to a first preferred embodiment of the invention may be constructed. Also this reactor as well as all those illustrated hereinafter is adapted to be connected to a three phase alternating voltage and has one winding per phase, although the invention, as already mentioned, not at all is restricted thereto. The windings are here led around a magnetizeable core 9 in common, which has an annular shape. The windings 3-5 are here formed by a cable 10 in the form of a flexible electric conductor 11 with an envelope or sheath 12 able to confine the electric field created around the

conductor. The very construction of such a cable will be described further below. An advantage of using such a cable exactly in the case of a core in common is that it gets easier to insulate the different phases with respect to each other.

The magnetic flux generated in the core 9 will on symmetry of the alternating voltage be substantially zero, since the flows of the different phases will cancel out each other and there will only be a comparatively low leakage inductance of the reactor as a consequence of leakage fluxes in the air. Thus, the flux in common felt by all the windings is in the practise when symmetry prevails substantially zero, and the respective phase feels substantially only the own leakage flux, whereas on asymmetry the windings will feel the flux in common through the core.

A reactor according to an embodiment as shown in fig 3, in which the different windings are intermixed in the sense that turns of winding belonging to the same winding have turns of winding belonging to another winding and another phase completely or partially therebetween. It is in this way possible to reduce the leakage fluxes and by that the leakage inductances of the reactor. Such a close mixing of the windings is only possible thanks to the use of a cable with the characteristics defined above, i.e. which encloses the electric field created around the conductor.

A reactor according to another preferred embodiment of the invention is illustrated in fig 4, in which a magnetizeable core 9 surrounds the windings. A reactor of this type is usually called a mantel reactor. The core has the shape of a toroid, i.e. is a continuous annular tube, and the reactor is substantially symmetric with respect to rotation around the axis 13. The windings are in fact not completely symmetric with respect to rotation, but they are helical.

A reactor according to the invention having a core 9 in common to the windings with a conventional rectangular shape is illustrated in fig 5, in which the windings are led around two of the legs 14, 15. An airgap 16 is here arranged in the core, which makes it possible to linearise the zero sequence inductance, which often would be desired. However, this means that the current limiting capacity of the reactor will be slightly lower as a consequence of the reduction of the zero sequence inductance.

Fig 6 illustrates a modification of the embodiment according to fig 5 without air gap and with windings mixed for reducing the leakage fluxes.

A reactor according to a further advantageous embodiment is illustrated in fig 7, and this reactor is a so-called air reactor, i.e. it has an air core 17. It is important that the windings of such an air reactor belonging to different phases are arranged close to each other, since it may otherwise not be achieved that the windings will feel substantially the same magnetic flux. A disadvantage of an air reactor is that it is not possible to obtain such a high inductance and by that current limiting effect on asymmetry, but an air reactor may instead be cheaper, since it has no iron core, and it may possibly also be dimensioned for a higher magnetic fields on asymmetrical supply, such as 5T, instead of for example 2T of a reactor with an iron core, so that the entire construction may be compressed. The reactor is mainly symmetric with respect to rotation around the axis 13, but not completely, since the windings are helical.

A further embodiment of a reactor according to the invention is illustrated in fig 8, in which the windings are led around the inner leg of a conventional core having three legs. Such a reactor is usually called to be of "shell-type". The flux in common will here be led in the middle leg, while the two other legs will function for return conduction of the flux to the middle leg.

A still further embodiment of the invention is shown in fig 9, which illustrates a so-called flat air reactor. Such an air reactor is more common than such ones according to fig 7. This is due to the fact that it is possible to obtain a higher inductance in such a flat reactor than in a long thin reactor, when the same cable length is used.

The rectors described above will through the design thereof automatically function as filter for distinguishing harmonics being multiples of three, i.e. the third, sixth, ninth harmonic and so on, whereas the fundamental tone will not be noticeably influenced.

The construction of a cable of the type having an inner electric conductor with an envelope able to confine the electric field created around the conductor and particularly well suited to be used in a reactor according to the invention is illustrated in fig 10. This cable has an inner flexible electric conductor 11 and an envelope 12, which forms an insulation system, which comprises an insulation 18 formed by a solid insulation material, preferably a material on polymeric basis, and an outer layer 19 having an electrical conductivity being higher than that of the insulation is arranged outside the insulation so that the outer layer through connection to earth or otherwise a comparatively low potential will be able to on one hand operate to equalise potential and on the other primarily enclose the electric field created as a consequence of said electric conductor 11 interiorly of the outer layer 19. Furthermore, the outer layer should have a resistivity being sufficient for minimising the electric losses in the outer layer. The insulation system comprises also an inner layer 20, which has said at least one electric conductor 11 arranged interiorly thereof and has an electrical conductivity being lower than that of the electric conductor but sufficient for making the inner layer to operate for equalising potential and by that act equalising with respective the electric field outside the inner layer. Thus, such a cable is of a type corresponding to cables having a

solid extruded insulation and today being used within power distribution, for example so called PEX-cables or cables with EPR-insulation. The term "solid insulation material" used means that the winding has to be without any liquid or gaseous insulation, for example in the form of oil. The insulation is instead formed by a polymeric material. Also the inner and outer layers are formed by a polymeric material, although a semiconducting one. The insulation 18 may be made of a solid thermoplastic material, such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybuthylene (PB), polymethylepenten (PMP), cross-linked polyethylene (XLPE) or rubber such as ethylene-propylene rubber (EPR) or silicon rubber. With respect to the resistivety of the inner layer and the outer layer this should be within the range $10^{-6}\Omega cm$ – $100k\Omega cm$, suitably 10^{-3} - $1000\Omega cm$, preferably $1\text{-}500\Omega cm$. The inner and the outer layer have advantageously a resistance which per length meter of the conductor/insulation system is in the range $50\mu\Omega$ - $5M\Omega$.

The electric load or stress on the insulation system is reduced as a consequence of the fact that the inner and outer layers of semiconducting materials around the insulation will tend to form substantially equipotential surfaces and the electric field in the insulation will in this way be distributed comparatively homogeneously over the thickness of the insulation.

The adherence between the insulation material and the inner and outer semiconducting layers has to be uniform over substantially the entire interface thereof, so that no hollow spaces, pores and the like may be created. This is of course particularly important in high voltage applications, and a cable of this type has preferably an insulation system adapted for high voltage, suitably over 10kV, especially over 36kV and preferably over 72,5kV. Electrical and thermal stresses occurring at such high voltages make high demands on the insulation material. It is known that so-called partial discharges ,PD, in general is a se-

vere problem for the insulation material in high voltage applications. Would hollow spaces, pores or the like be formed in an insulating layer, inner corona discharges may occur at high electrical voltages, whereby the insulation material is gradually degraded and the result could be electrical breakdown through the insulation. This could result in a severe breakdown of the reactor.

It is advantageous that the inner and outer layers and the solid insulation have substantially the same thermal properties for avoiding the generation of such hollow spaces or pores, in which it is particularly important that they have substantially the same coefficient of thermal expansion, so that a perfect adherence between the different layers may be maintained during temperature changes thereof and the cable expands and contracts uniformously as a monolithic body upon temperature changes without any destruction or degradation of the interfaces. The insulation layer is for example a PEX-cable of cross-linked low-density polyethylene and the semiconducting layers of polyethylene with dust and metal particles admixed. Volume changes as a consequence of temperature changes are absorbed entirely as changes of the radius of the cable, and thanks to the comparatively small difference of the coefficients of thermal expansion of the layers with respect to the elasticity of these materials, the radial expansion of the cable may take place while avoiding that the layers will get loose from each other.

The cable has also to have a certain flexibility, and it is flexible down to a times radius of curvature below 25 x the diameter of the cable so that bending may take place while ensuring a good adherence between the respective layers and the solid insulation. The cable is suitably flexible to a radius of curvature below 10 x the diameter of the cable, and preferably to a radius of curvature below 5 x the diameter of the cable. The E-modulus of the different layers in the insulation system should be substantially equal so as to not induce any unnecessary shearing

stresses in the interfaces between the different layers, so that a reduction of the shearing stresses that may be created between the different layers when exerting the cable to powerful bending resulting in tension stresses on the outside of the bend and compressive stresses on the inside of the bend may take place.

The invention is of course not in any way restricted to the preferred embodiment described above, but many possibilities to modifications thereof would be apparent to a man with ordinary skill in the art without departing from the basic idea of the invention such as defined in the appended claims.

The windings could of course be arranged in another mutual way than shown in the figures, and it may still be obtained that they feel substantially the same magnetic flux, in which these in some cases could be arranged further apart so as to obtain a certain leakage inductance desired.

The magnetic material may also surround the windings as already mentioned and shown. The case in which three phases surrounds a magnetic tube corresponds to a reactor having one turn per winding. If there are more turns they may be closed externally of the tube. If the tube is closed in for example a circle the turns may be closed entirely inside the tube. The latter case corresponds to a mantel reactor discussed above. The magnetic material has neither to surround the windings " the entire turn around". The magnetic material could as in the core usually called "shell-type" be closed outside the windings in two magnetic return conductors covering only a small part of the periphery of the windings. The tube has not to be made in one single piece. It may consist of several pieces mounted together, but it may also be formed by winding a magnetic tape or wire around the phases. The cross-section of the tube may be arbitrary circular, rectangular and so on.

Different combinations of airgap of a reactor core are also possible. The list of possible modifications of the construction of the reactor according to the invention within the scope of the idea of the invention could be made indefinitely long.

Claims

1. A reactor comprising a plurality of windings (3 – 5) each adapted to be connected to one phase (6 – 8) of a multiphase alternating voltage, said windings being configurated so that they upon connection to said voltage are influenced by substantially the same magnetic flux, ***characterized*** in that at least one of said windings (3 - 5) is at least partially formed by a cable (10) in the form of a flexible electric conductor (11) with an envelope (12) able to confine the electric field generated around the conductor.

2. A reactor according to claim 1, ***characterized*** in that the number of phases (6 – 8), the number of windings (3 – 5), the winding direction of the windings and the number of turns per winding are so selected that the sum of the currents flowing in said windings and driving the magnetic flux in common is substantially zero when the windings are symmetrically supplied with the multiphase alternating voltage.

3. A reactor according to claim 1 or 2, ***characterized*** in that the number or phases is three.

4. A reactor according to any of claims 1 – 3, ***characterized*** in that the windings belonging to different phases are arranged close to each other.

5. A reactor according to any of claims 1 - 4, ***characterized*** in that the winding turns of the different windings (3 – 5) run in the same direction as seen in a direction away from a location for connection to the multiphase alternating voltage.

6. A reactor according to any of claims 1 – 5, ***characterized*** in that the windings are led around a closed magnetic circuit (9, 16) in common.

7. A reactor according to any of claims 1 – 5, ***characterized*** in that it comprises a closed magnetic circuit in common to and surrounding the windings.

8. A reactor according to claim 6 or 7, ***characterized*** in that the magnetic circuit (9, 16) consists of one or more materials possibly having different magnetic properties and which may be connected in an arbitrary number of combinations.

9. A reactor according to claim 6, 7 or 8, ***characterized*** in that at least one of the materials in the magnetic circuit (9, 16) is iron or an iron alloy.

10. A reactor according to any of claims 6, 7 or 8, ***characterized*** in that the magnetic circuit (9) consists entirely of iron or an iron alloy.

11. A reactor according to any of claims 6 – 9, ***characterized*** in that at least one of the materials (9, 16) in the magnetic circuit (16) is non-magnetic.

12. A reactor according to claim 11, ***characterized*** in that one of the non-magnetic materials (9, 16) is air.

13. A reactor according to claim 12, ***characterized*** in that the magnetic circuit (17) consists entirely of air.

14. A reactor according to claims 6 – 12, ***characterized*** in that the magnetic circuit has at least one air gap (16).

15. A reactor according to any of claims 6 – 14, ***characterized*** in that said magnetic circuit (9, 16) surrounds a circular area.

16. A reactor according to any of claims 6 –14, ***characterized*** in that said magnetic circuit (9, 16) surrounds a rectangular area.

17. A reactor according to any of claims 6 – 14, ***characterized*** in that said magnetic circuit (9, 16) surrounds a triangular area.

18. A reactor according to any of claims 6 – 17, ***characterized*** in that each phase (6 – 8) is connected to only one winding (3 – 5) having only one turn.

19. A reactor according to claim 18, ***characterized*** in that said turn may form a loop being considerably wider than the area around the reactor.

20. A reactor according to any of claims 6 – 19, ***characterized*** in that the windings (3 – 5) run through their winding turns around said magnetic circuit (9, 16) and surround it entirely or over portions.

21. A reactor according to any of claims 6 – 19, ***characterized*** in that the windings (3 – 5) surrounds a part or a few parts of said magnetic circuit (9, 16) through the winding turns thereof.

22. A reactor according to any of claims 6 - 19, ***characterized*** in that the magnetic circuit (9, 16) surrounds the windings entirely or over portions thereof.

23. A reactor according to any of claims 6 – 19, ***characterized*** in that the magnetic circuit (9, 16) surrounds a part or few parts of the winding.

24. A reactor according to any of claims 1 – 23, ***characterized*** in that the windings are arranged on a carrier in common of non-magnetic material.

25. A reactor according to any of claims 1-24, ***characterized*** in that all windings are formed by a said cable.

26. A reactor according to claim 24 or 25, ***characterized*** in that the different windings (3 – 5) are at least partially intermixed in the sense that turns of winding belonging to the same winding have turns of winding belonging to another winding and another phase entirely or partially therebetween.

27. A reactor according to any of claims 24 – 26, in which the envelope comprises an insulation system, ***characterized*** in that the insulation system comprises an insulation (18) formed by a solid insulation material and outside thereof an outer layer (19) having an electrical conductivity which is higher than the electrical conductivity of the insulation so that the outer layer may through connection to earth or otherwise with respect to low potential be able to on one hand operate for equalizing potential and on the other substantially enclose the electrical field generated as a consequence of said electric conductor (11) inwardly of the outer layer.

28. A reactor according to any of claims 24 –26, in which the envelope comprises an insulation system, ***characterized*** in that the insulation system comprises an insulation (18) formed by a solid insulation material and an inner layer (20) interiorly thereof, that said at least one electric conductor (11) is arranged interiorly of the inner layer and that the inner layer has an electrical conductivity being lower than the electrical conductivity of the electric conductor but sufficient for making the inner layer to operate to equalize potential and by that to equalize the electric field outside the inner layer.

29. A reactor according to claim 27 or 28, ***characterized*** in that the inner and outer layers and the solid insulation have substantially equal thermal properties.

30. A reactor according to any of claims 27 – 29, ***characterized*** in that the inner and/or outer layer (19, 20) comprises a semiconducting material.

31. A reactor according to any of claims 27 – 30, ***characterized*** in that the inner layer and/or the outer layer (19, 20) has a resistivity in the range $10^{-6}\Omega$cm – 100kΩcm, suitably 10^{-3} - 1000Ωcm, preferably 1-500Ωcm.

32. A reactor according to any of claims 27 – 31, ***characterized*** in that the inner layer and/or the outer layer (19, 20) has a resistance which per length meter of the conductor/insulation system is in the range 50$\mu\Omega$ - 5MΩ.

33. A reactor according to any of claims 27 – 32, ***characterized*** in that a solid insulation (18) and the inner layer (20) and/or the outer layer (19) are formed by polymeric material.

34. A reactor according to any claims 27 –33, ***characterized*** in that the inner layer (20) and/or outer layer (19) and the solid insulation (18) are rigidly connected to each other over substantially the entire interface to ensure adherence also on flexing and temperature change.

35. A reactor according to any of claims 27 – 34, ***characterized*** in that the solid insulation (18) and the inner layer (20) and/or the outer layer (19) are formed by materials having a high elasticity to maintain mutual adherence on strains during operation.

36. A reactor according to claim 35, ***characterized*** in that the solid insulation (18) and the inner layer (20) and/or the outer layer (19) are of materials having substantially equal E-modulus.

37. A reactor according to any of claims 27 – 36, ***characterized*** in that the inner layer (20) and/or the outer layer (19) and the solid insulation (18) are formed by materials having substantially equal coefficients of thermal expansion.

38. A reactor according to any of claims 27 – 37, ***characterized*** in that the inner layer (20) is in electric contact with the at least one electric conductor (11).

39. A reactor according to claim 38; ***characterized*** in that said at least one electric conductor (11) comprises a number of strands and that at least one strand of the electric conductor is at least in part uninsulated and arranged in electric contact with the inner layer (20).

40. A reactor according to any of claims 27 – 39, ***characterized*** in that the conductor and its insulation system are designed for high voltage, suitably over 10 kV, in particular over 36kV and preferably over 72,5kV.

41. A reactor according to any of the preceding claims, ***characterized*** in that it is adapted to be connected through the windings to a high voltage, suitably over 10kV, in particular over 36kV and preferably over 72,5kV.

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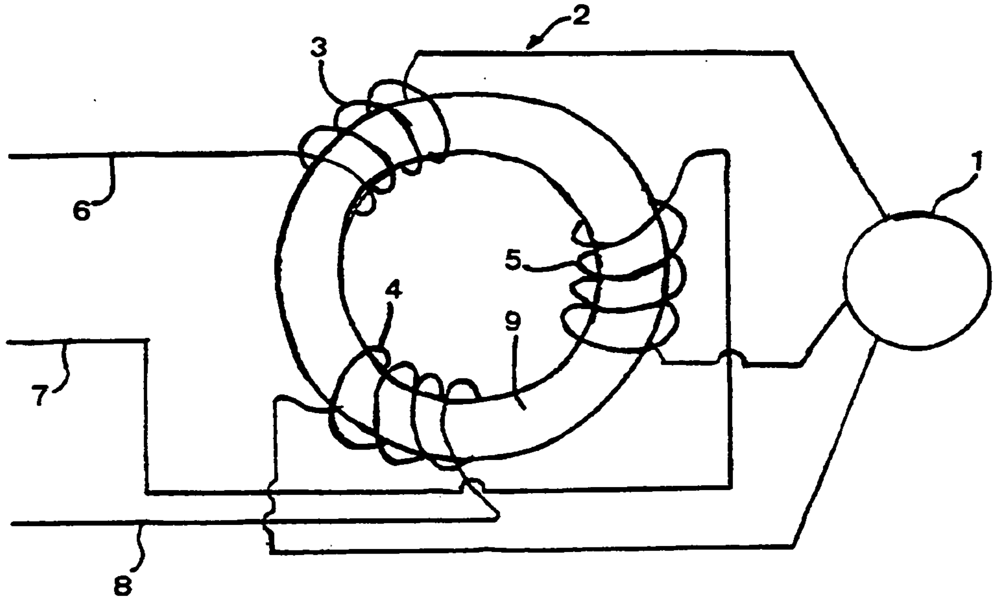


Fig 1

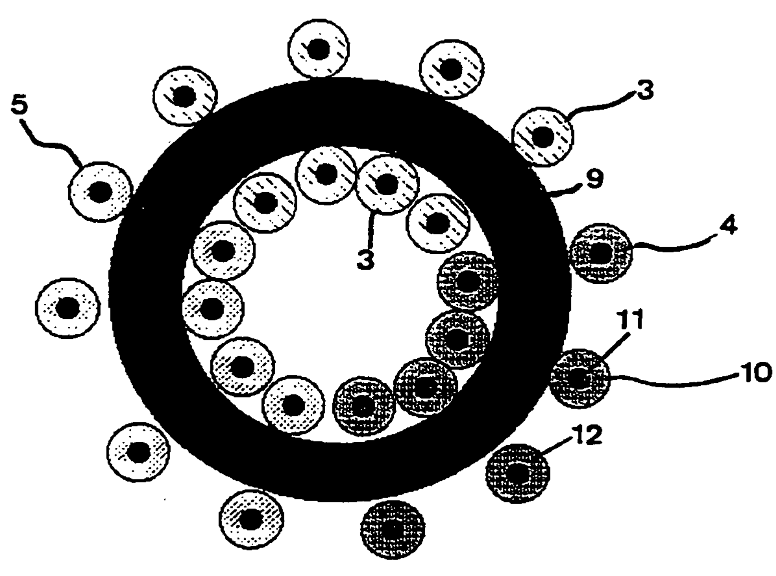


Fig 2

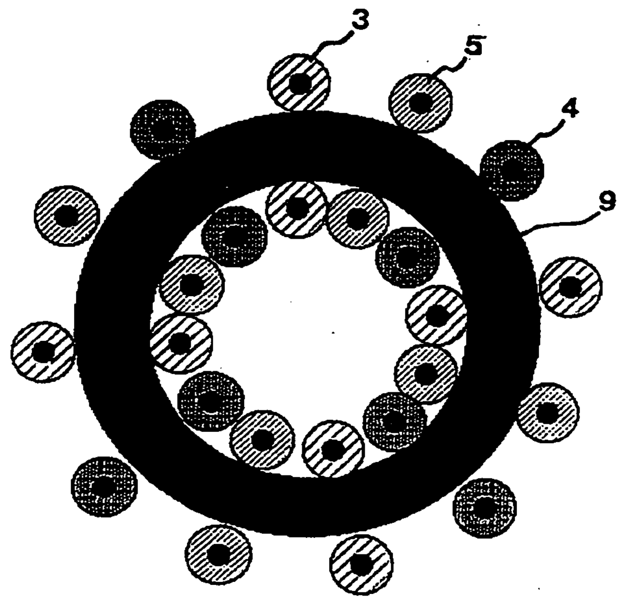
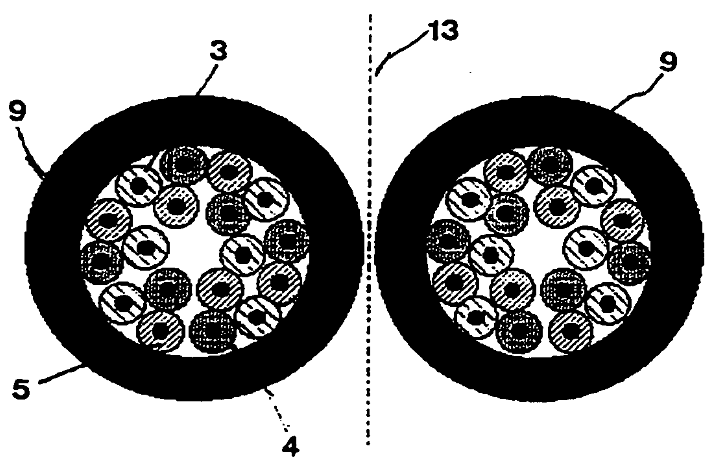


Fig 3



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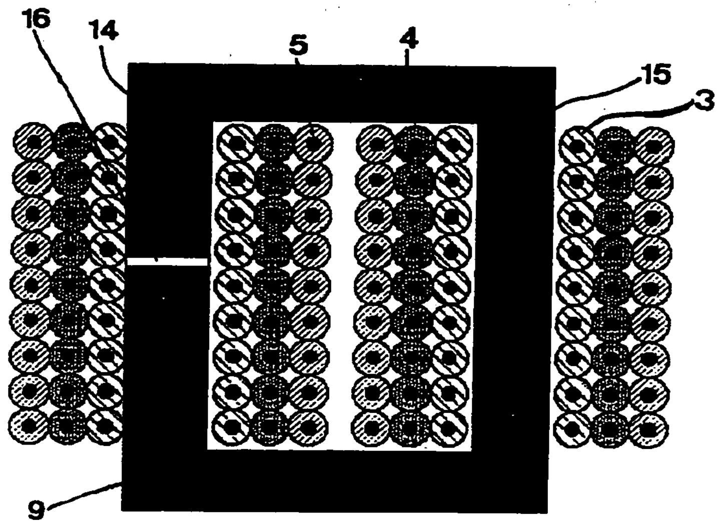

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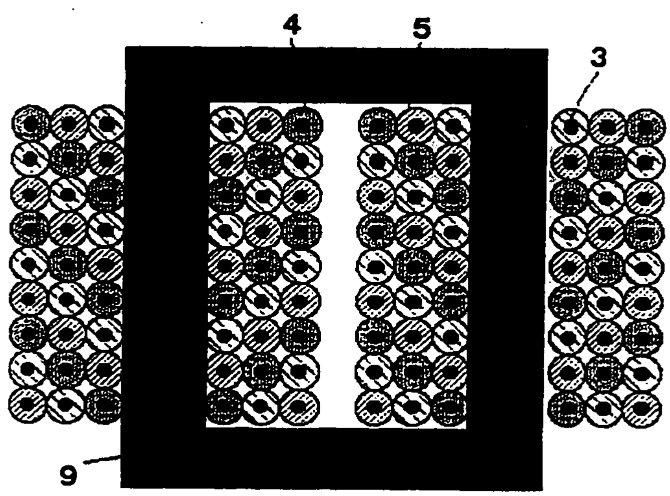

Fig 6

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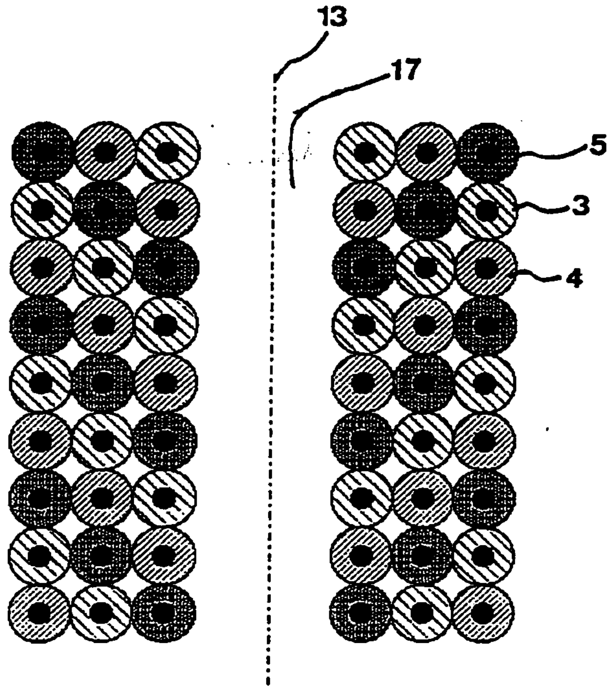

Fig 7

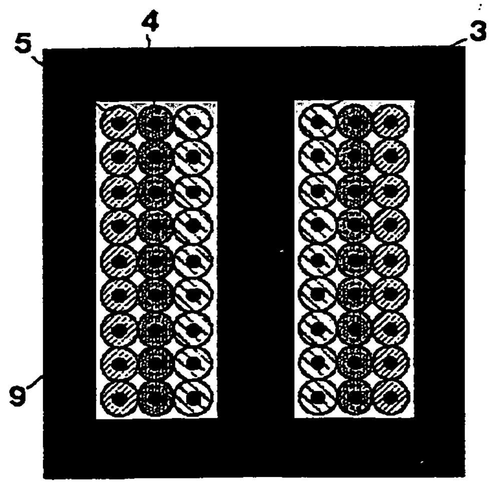

Fig 8

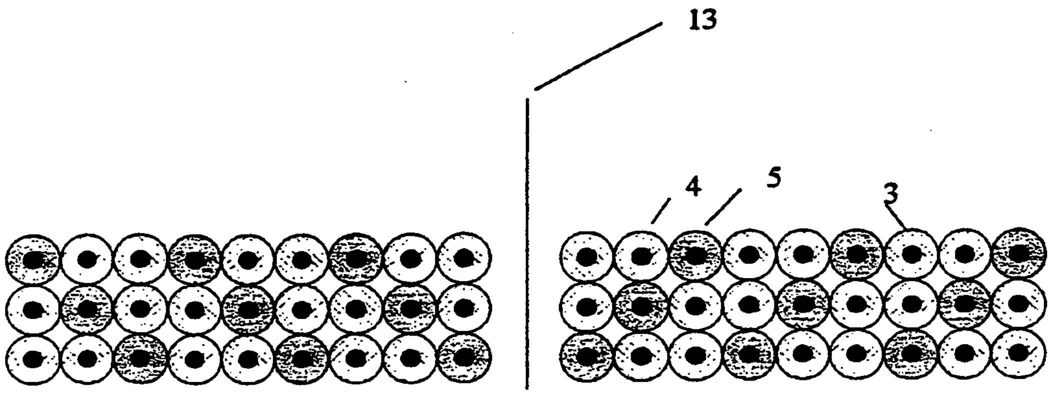

Fig 9

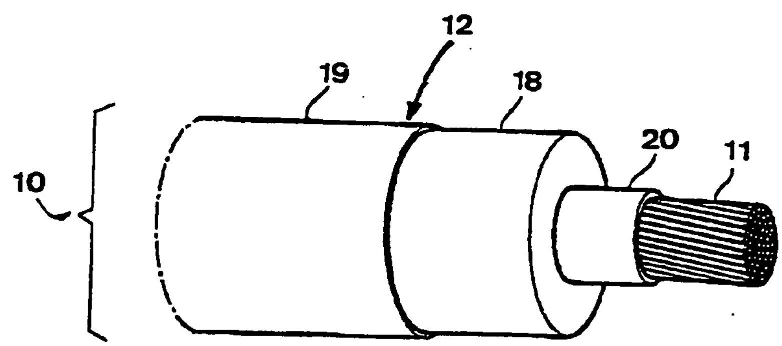

Fig 10

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